Wind Power

Wise move or waste of time?

By Gregg Grant

greg@grantg52.fsnet.co.uk

The UK Government recently announced the world's biggest ever expansion in wind energy. So how realistic is this scheme? What are the pitfalls, technical and otherwise, and how viable is it economically? It's time to look at wind generation in the round.

Wind is simply air in motion, with mass and energy. It has been used for centuries, the most obvious example being windmills. In 1850 the American Daniel Halliday developed the 'multi-bladed' farm windmill, a relatively simple device that inspired the first attempts to convert wind into a form of energy that could be either stored for future use, or applied elsewhere.

As electrification gradually spread to rural areas in both Europe and America, windmill-driven generators became fairly common in the more remote areas of both continents.

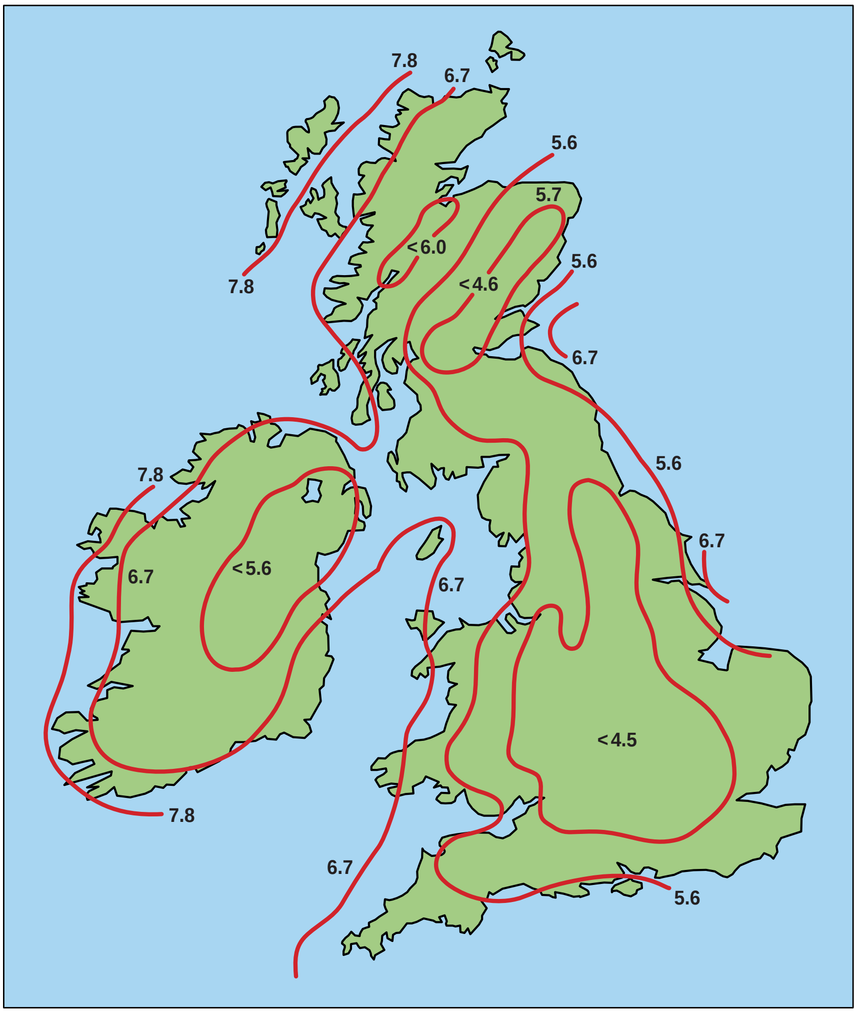
By 1890 Denmark — a nation without natural energy resources such as coal or waterfalls — had some 7000 of these windmill generators in operation, they delivering around a quarter of the country's power requirements. Consequently, the Danish government of the day decided to further develop wind-powered electric generators.

By the turn of the last century, some 72 generators, the first of their kind, had been built. They comprised a 25-metre high tower, which supported a four-bladed rotor some 22 metres in diameter, which was coupled by a drive system to a ground-based generator. These wind driven devices continued to feed power into the Danish national grid system until 1968, when the last working machine was shut down, for economic reasons.

In America meanwhile, on-going wind power developments were mainly a matter of manufacturing and marketing what was termed 'wind chargers.' These were two-occasionally three-bladed propellers, some four metres in diameter, capable of supplying sufficient electricity to power a couple of lights, a radio and (perhaps) a washing machine or refrigerator.

Some 500,000 of these power sources were delivering power across the Midwest until, in 1960, the Rural Electrification Administration, the REA, finally connected the region to the national grid.

In Europe too a number of engineers and inventors were attempting to discover efficient ways of harnessing the energy of the wind. In 1922, the Finnish engineer Sigurd Savonius developed the rotor named after him. It comprised semi-circular blades, built from two sec-



030370 - 11

Figure 1. UK windforce distribution chart.

tions of an oil drum, cut in half along its vertical axis, and welded together with an offset from the axis to form an 'S' shape. In the 1970s, a modern version of this wind device was set to work in America, it generating some 5 kW of electricity in a 12-metre/second wind.

Nine years after Savonius, the French power engineer Georges Darrieus patented a wind turbine design whose blades were manufactured from twisted metal strips, which were attached to the top and bottom of the shaft and bowed out in the middle, rather like the blades of a food processor. This device however had a drawback: it was not self-starting. Nevertheless an example of this arrangement, with aluminium blades, was built at the Sandia National Laboratory in America and, during trials, generated around 60 kW of electricity in a wind blowing at slightly more than 12 metres/second.

However, the most effective wind generators appeared to be those based on the classic 'Dutch' propeller, for it was the Dutch who carried out much of the early technical investigation into wind power. Indeed it was just such a system that the Americans opted for when they created their first major wind generator project in 1939.

Palmer Puttnam, the engineer in charge, chose a windswept hill in Vermont as the location for the generator, which was driven by two, eight-ton stainless steel blades, some 53 metres in diameter. Completed in 1941, this generator began to feed some 1500 kW into the national grid. Four years later however disaster struck when one of the blades flew off the shaft and ended up in a crumpled mess, some 240 metres away. The project was later abandoned.

The technological advances of the last half-century however have made wind power a viable alternative to fossil fuels and by the mid 1990s, a number of designs were being investigated in the United States (US), Europe and the United Kingdom (UK).

Wind Generation

There are three factors governing the conversion of wind into electrical power. They are wind speed, the conversion factor and the form and size of the turbine blades.

Wind Speed

The UK is in an enviable position where wind speed is concerned, as a glance at **Figure 1** illustrates. The highest winds occur along the Atlantic-facing coasts of the British Isles, giving the UK some 40% of Europe's total realisable wind energy potential.

Wind power is related to the cube of the wind's speed or, put another way, if windspeed doubles, wind power increases eightfold. In fact during gale or storm force winds, windspeed can be as much as five times greater than the average windspeed for which the turbine was designed. This means that the stress acting on it rises way beyond the standard operating value.

Conversion Factor

The faster the wind, the speedier the movement of the turbine and therefore the greater the electrical energy generated. In short, power output increases with windspeed, although there is obviously no power delivered when the wind is too low.

The majority of commercial devices begin to provide a small output in windspeeds of about four metres/second. As the windspeed increases, so also does the power delivered until the rated power output is reached.

Turbine Form and Size

Two-bladed turbines are more common as they produce a higher maximum speed, although the three-bladed design of **Figure 2** makes for greater stability and so more vibration-free operations. The power produced is proportional to the square of the blade diameter which means that - for a standard horizontal axis turbine - doubling the area of the circle traced by the rotating blade tip, doubles the power generating potential.

Currently, blade manufacture is much influenced by aeronautical technology in particular sailplane wings. Blades are arranged so that the forces generated thrust the rotor around in a circular path, thus achieving a balance between maximum lift and

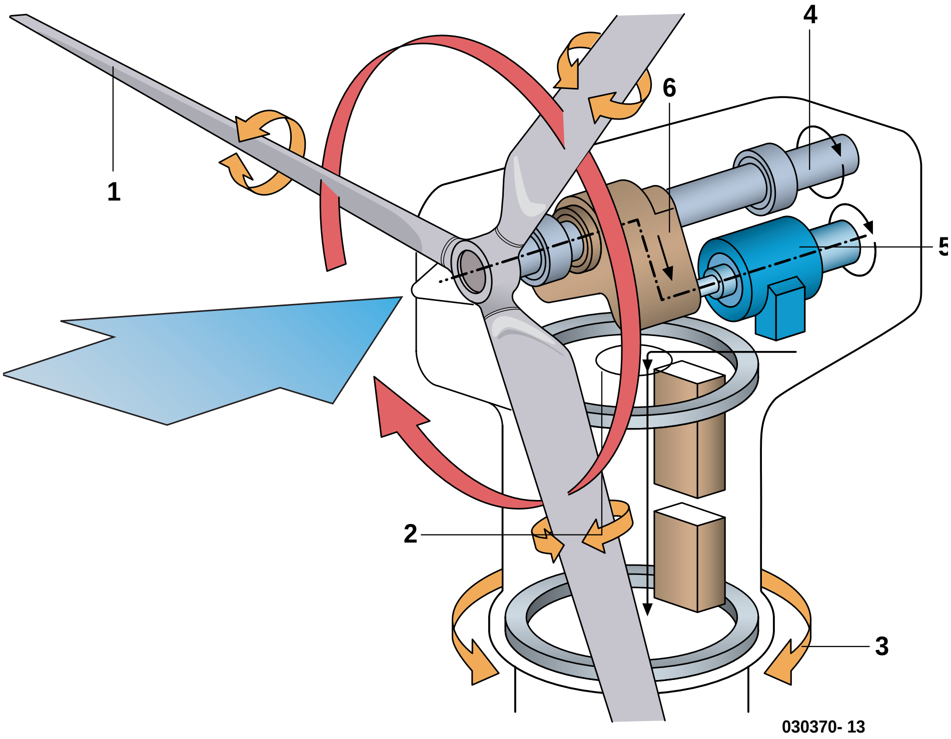


Figure 2. Basic design of a 3-blade turbine.

minimum drag. Presently, modern turbine blades rotate around 10 times faster than the basic windspeed.

The Equipment

Current turbine designs are twice as efficient as the designs of 20 years ago and the cost of these machines has been reduced by a factor of three over the same period. Presently, some designs are rated in hundreds of kilowatts, and shortly larger devices — sometimes referred to as aerogenerators — capable of delivering 20 megawatts and with turbine blades some 50 metres in diameter are coming on-stream.

In Figure 2, the three-blade turbine (1) can have the attitude of its blades altered. By changing the pitch (2) the blades can operate at maximum efficiency in changing wind conditions.

As the entire rotor assembly (3) moves into the wind, the blades turn the prop shaft (4), which is coupled to the generator (5) via the gearbox (6). The three-blade, variable pitch arrangement has proved to be the most efficient design and the largest wind farms comprise thousands of such turbines, linked together, and capable of generating as much electricity as a fossil fuel power station.

The UK's first commercial wind farm, made up of ten Danish wind turbines rated at 400 kW each and able to supply electricity to some 3000 homes, was connected to a part of the national grid in December 1991. At the same time, some 500 Megawatts of power were being generated on the continent, the majority of it in Denmark.

By far the largest rise in wind power generation took place in the US, throughout the 1980s. Generous federal tax incentives created around 1500 megawatts of installed capacity; again much of it generated on Danish machines. The Danes are one of the few nations with a viable wind generator manufacturing industry, which exports its products worldwide. During the upturn in wind power generation in the US, the Danes were earning some £130 million per annum in export sales.

Although there is enough wind circulating day and night to supply the entire planet's energy requirements — despite the fact that only some 2% of the sunlight falling on the Earth is converted into wind energy — this potential power is spread thinly. That said, wind power is expanding at 20% per annum and has been for the last decade. Indeed as a growth industry it has few rivals, not even gas or oil. In the US for example, the states of Texas and North and South Dakota have sufficient usable wind to meet the present electrical power requirements of America as a whole.

Drawbacks

Firstly there is the no small matter of constancy, secondly the interference wind turbines cause to radar and thirdly, no one has yet produced a cost-effective method of storing the excess energy that builds up when the wind does blow. Finally, one of the more astonishing drawbacks is the objection of the environmental lobby.

They – it seems – have four principal gripes firstly excessive noise, secondly the detrimental effect on the landscape, thirdly the impact on local flora and fauna and finally the huge amount of land taken up by wind farms.

Noise is the least of the above concerns as **Figure 3** illustrates. For example, a person standing some 43 meters from a wind turbine would experience a noise level no greater than that she or he would be subjected to in an average house throughout a normal day. Furthermore a wind farm of 30, 300-kW turbines produces only 45 dB of noise, some 500 meters from the nearest turbine. This is little more than half of the figure considered damaging to the human ear i.e. 80 dB.

Even in terms of the detriment to the landscape the environmental lobby are hardly on solid ground. Wind turbines are no more unsightly than electricity pylons, structures that have long been accepted, even by the eco lobby. Once set up, around 98% of the land used for a wind farm can return to its natural state, thus encouraging (perhaps) a wider variety of flora and fauna to the area than had been there formerly. As to their effect on wildlife, the environmentalists do have a point. Wind turbines, for obvious reasons, are located in open areas, frequently on high moorland, exactly the sort of territory birds of prey frequently hunt in.

The radar problem is something else again and is one of the biggest hurdles faced by the industry, according to the British Wind Energy Association. The Ministry of Defence, the MOD, for example opposes some 34% of all new proposals for wind farms.

Turbines can be as high as 180 metres which, coupled with their method of rotation, means that radar signals reflected by them can be as much as 1000 times stronger than those reflected from a light aircraft. They are also difficult to filter out, since a radar can pick up different blades with successive scans, interfering with the echoes from aircraft flying above the wind farm.

The problem can be reduced by manufacturing blades that are virtually invisible to radar, thus reducing the signal strength such that it can be filtered out in the same way as echoes from a building for example. The trick is to do this without either increasing manufacturing costs or reducing the strength of the blades.

The Costs Involved

Table 1 gives a comparison – for the early 1990s - of the cost of electricity generated from wind power compared to the three other major energy-generating technologies. Since that time of course, technology shares — and hence profits and finances generally — have taken a battering.

However, from April through to July this year, technology stocks have been doing moderately well, those that survived the crisis that is. Yet they only attracted £9 million in new money in March, compared with the massive £879 million they pulled in during March 2000.

Given the above, what convinced the UK government and to a certain extent the City, that wind power was the way ahead in terms of energy? Furthermore, what should we read into the fact that the government has actually put up money for investment and support of wind power development?

Two things: the UK's commitment to the Kyoto Protocol, in which the planet's industrialised nations have agreed to cut carbon dioxide emissions by 10% by 2010, and the government's idea that wind power is capable of providing electricity to one in every six British homes.

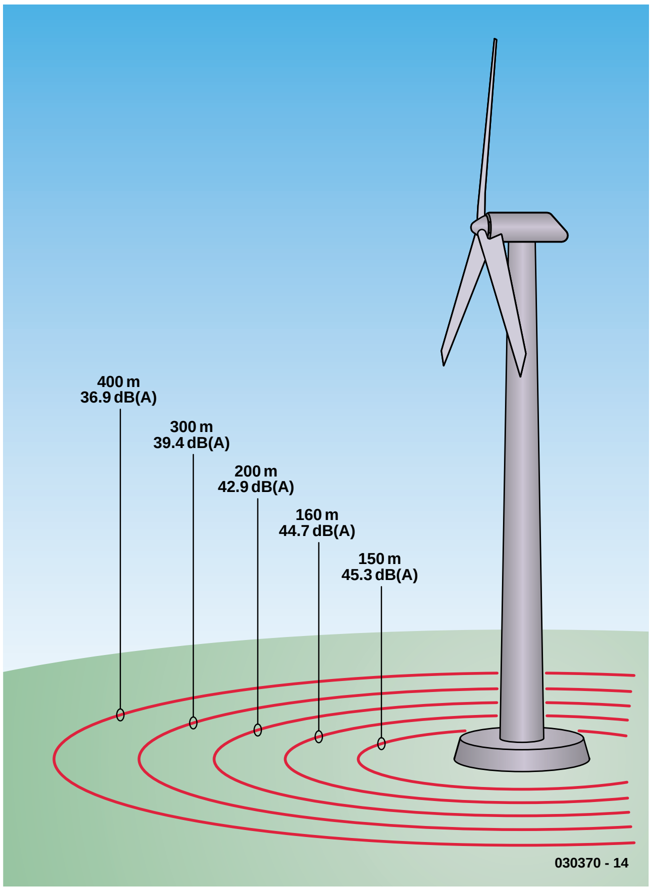


Figure 3. Noise footprint of a typical 3-blade wind turbine.

Table 1: Power Generation Costs.

Technology	**Cost** (Pence/ kilowatt/hour)
Coal	3.5 to 4.0 pence
Gas	2.3 to 2.8 pence
Nuclear Power	5.0 to 7.5 pence
Wind Power	2.9 to 5.2 pence

Whilst the government may be enthusiastic about wind power, the City remains cautious, for the subject involves what money men term 'early-stage' investment, which makes forecasting the return on capital expenditure problematical to say the least.

They also perceive a technological risk for although wind energy, both on-shore and off-shore, has a considerable amount of research and development behind it, no one has done it before on the scale the government's planning. The question for the City is this: will offshore wind generators deliver over the long haul?

Presently, the two biggest organisations providing wind-generated power in the UK are Power Gen Renewables and National Wind Power. The former generates some 120 Megawatts (MW) from its 16-unit Bowbeat Hill wind farm near Peebles. Currently the UK's largest such installation, it provides half the power required by homes in the Borders region. National Wind Power has 14 on-shore units generating around 160 MW.

However, the perceived detrimental effect of such installations on the landscape – touched on earlier – has led to the industry moving off-shore, and National Wind Power is scheduled to complete the UK's first off-shore wind farm on the North Wales coast, later this year. Power Gen Renewables too has opted to move offshore, and its new installation off Great Yarmouth is due to go on-line in autumn 2004.

The UK government regards offshore wind power generation as capable of providing electricity to one in every six British homes. This is one aspect of its £6bn plan to make the UK the world's largest offshore wind farm developer. If this seems a great deal of money it's not surprising, for offshore wind farms are some 30% to 40% more costly to operate than on-shore ones.

Nevertheless, both companies are of the view that offshore installations will enable the UK to meet its commitments under the Kyoto agreement. Whether they will be able to deliver sufficient power to one sixth of the nation's homes at a competitive price, is another matter entirely.

(030370-1)